PENNSYLVANIA'S EFFORTS TO ADDRESS OPERATION, MAINTENANCE AND REPLACEMENT OF AMD PASSIVE TREATMENT SYSTEMS

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ABSTRACT

An increasing number of watershed groups, as well as many Federal, State and local agencies, have become active in watershed restoration over the past several years. As a result, a large number of restoration projects are being funded and constructed. In Pennsylvania, a total of nearly $93 million of public money has been spent on all types of watershed restoration projects since 1988. A portion of this funding has gone to construct 153 AMD passive treatment systems statewide. Funds have come from a variety of sources, including the Office of Surface Mining's Title IV program, the Natural Resources Conservation Service's (NRCS) PL-566 program, Pennsylvania's Growing Greener program and the Environmental Protection Agency's 319 Non-Point Source program. Water quality and aquatic habitat improvements are occurring as these projects are implemented. The need for long-term operation, maintenance and replacement (O, M & R) has been increasingly recognized as a requirement to ensure the success of watershed restoration projects. The failure to maintain the systems being constructed could have detrimental impacts to watersheds that are beginning to support an increasing number of stream uses. As a result of growing concern over this issue, the PA Department of Environmental Protection (DEP) established a workgroup to provide recommendations to address this need. The workgroup consisted of individuals from Federal, State and local governments, as well as private consultants and watershed group officials. All had extensive experience in the operation and maintenance of watershed restoration projects, both mining and non-mining related. Recommendations were finalized by late 2001.

The NRCS and DEP have taken a lead role in implementation of these recommendations, including the development of maintenance plans and agreements, working with local watershed groups to provide routine maintenance and trouble-shooting to solve problems that arise. Their experiences are providing a greater understanding of the efforts needed to keep systems functioning properly.

INTRODUCTION

In Pennsylvania, watershed groups and various government agencies started constructing passive treatment systems to treat abandoned mine drainage (AMD) in the early 1990's. The design of these systems has evolved from simple, aerobic wetlands to complex vertical flow alkalinity generating systems with mechanisms to flush accumulated metals. While the design improvements have resulted in the ability to treat highly acidic discharges, the resulting systems have required significantly more effort to keep them operating effectively. Early vertical flow systems that did not have adequate flushing mechanisms have started to fail due to plugging by metals. Additional problems have surfaced at older systems, including leaks, short-circuiting and metals accumulation. All these experiences have pointed to the need to address long-term operation, maintenance and replacement (O, M & R) of AMD passive treatment systems.

The need to address O, M & R became even more pressing as additional funding was made available to build these types of systems. Early on, funds were provided by the EPA 319 Non-Point Source program, the Natural Resources Conservation Service (NRCS) Rural Abandoned Mine Program and P.L. 566 program and the Federal Office of Surface Mining's Ten Percent Set Aside and Appalachian Clean Streams Initiative (ACSI) programs. These funds continue to increase, while significant additional funding has surfaced with the establishment of Pennsylvania's Growing Greener program in 1999.

In June 2000, State Representative Sam Smith provided remarks at a statewide AMD conference that emphasized the need to address O, M & R in watershed restoration work. Many others working in the AMD treatment field were recognizing the same need. As a result, the PA Department of Environmental Protection (DEP) established a workgroup in early 2001 to develop recommendations to address this problem. The workgroup met throughout 2001 and finalized recommendations to DEP Secretary David Hess in November, 2001. These recommendations are provided in Attachment A. Since that time, much effort has gone into implementation of the recommendations. The DEP and NRCS have been leaders in that effort, along with several strong watershed groups and knowledgeable consultants.

IMPLEMENTATION

A major focus of implementation of the workgroup's recommendations has been the educational aspect. Members of the workgroup spoke at various conferences and Growing Greener training workshops in order to develop an awareness of the need to address O, M & R. Also, several changes were implemented in the Growing Greener program (the single most significant funding source) as a result of the recommendations. They included: developing an O, M & R fact sheet, providing detailed information in the application packets about the need to address O, M & R in the application, changing project score sheets to emphasize the need for O, M & R on implementation projects, and requiring the development of an O, M & R plan for all construction projects. In addition, a separate funding category has been developed to address funding of O, M & R projects with significant costs, starting with the 2003 round. The State Legislature passed Legislation in late June that continues Growing Greener through 2012 and provides a permanent funding source for the program.

The development of O, M & R plans has become a major focal point for projects constructed by the NRCS, under their P. L. 566 program, and the DEP's Bureau of Abandoned Mine Reclamation (BAMR), which uses OSM and Growing Greener funds to construct treatment facilities. These plans emphasize the partnerships with local watershed groups that are needed to provide for necessary O, M & R. O, M & R plans are developed for all NRCS projects and all new BAMR projects. The NRCS requires local sponsors in counties where the projects are located to accept the responsibility for all O, M & R needs. Operation and maintenance agreements and plans are prepared for the sponsors. NRCS staff provides consultation and technical input when significant maintenance is needed. BAMR looks upon the local groups to provide for routine monitoring, operation and minor maintenance requirements. Training is provided to the local groups where needed. BAMR is responsible for more significant maintenance needs and for eventual system replacement.

A major issue with regard to O, M & R is monitoring, particularly water sampling and laboratory analysis. Monitoring of the treatment system efficiency is very important – it provides feedback for future design improvements and signals when systems are not operating properly and may need maintenance. Typically, local groups and BAMR staff collect the samples and DEP's laboratory provides the analysis. This has proven to be a significant portion of the expenses involved with O, M & R. Determining how best to deal with this cost is an ongoing issue within DEP that has yet to be resolved. The DEP has recently convened a small workgroup to address this.

TECHNICAL ISSUES

A number of difficult technical issues have arisen with regard to the long-term operational efficiency of AMD passive treatment systems. The most complex issue deals with metals precipitation within the systems, particularly vertical flow systems that treat net acid water. Vertical flow systems typically consist of a layer of standing water over organic material (usually mushroom compost), which is underlain by limestone with a pipe collection system below the limestone. In theory, vertical flow systems are expected to keep ferrous iron in the ferrous state and to reduce existing ferric iron to a ferrous state as a result of a lack of oxygen in the system (the compost layer strips oxygen present in the water as a result of the biological oxygen demand of the compost). Ferrous iron is expected to pass through the limestone and precipitate in a subsequent settling basin. Aluminum, which comes out of solution as the pH increases, whether or not oxygen is present, is expected to precipitate within the compost and/or limestone layer. Flushing is expected to remove precipitated aluminum. However, field evidence indicates that most systems retain some iron within the limestone. In a few cases, iron has precipitated on top of the compost layer, causing the system to plug. While flushing these systems provides visual evidence of both iron and aluminum removal from the systems, a recent study has indicated that only a small percentage of retained metals is being flushed from the system in two systems studied (Watzlaf, 2001). The long-term implication of this is unknown, but efforts are underway to determine the best way to design the flushing systems to maximize removal from the limestone.

A less frequent problem occurs when ferric iron precipitates on top of the compost in vertical flow systems, as the pH starts to increase. When this occurs, it eventually reduces the permeability of the compost until water cannot flow vertically through the system. Since the solubility of iron is pH dependent and precipitation occurs more rapidly as the pH increases (Hem, 1992), the pH of the raw water that is being treated must be carefully considered when designing systems with high iron levels. Creating larger precipitation ponds and wetlands before the vertical flow systems can reduce the amount of ferric iron reaching the vertical flow system.

Accumulation of aluminum in the top 6 inches of the rock layer in vertical flow systems can create hydraulic conductivity problems within the limestone. As mentioned earlier, oxygen is not needed to precipitate aluminum - there only needs to be an increase in pH to above 4.5 (Hem, 1992) for precipitation to occur. In many systems, this pH increase occurs in the upper areas of the limestone rock column, or even within the compost. The initial precipitation of aluminum creates a very loose, jelly-like precipitate ($2Al(OH)_3$) that is easily dislodged and flushed from the rock. This precipitate is easily flushed from the system when aggressive flushing systems are initially designed in the system. Frequent flushing is recommended, at least quarterly, to keep the aluminum purged from the system. Field observations indicate that if the aluminum is allowed to accumulate in the rock to point where hydraulic conductivity is reduced, the flushing of aluminum becomes more difficult. Also, aluminum precipitate seems to harden and take on a paste consistency with time and becomes harder to flush.

Other problems encountered with vertical flow systems include short-circuiting caused by the development of preferential flow paths through the compost layer. This has especially been evident on several systems where the compost was washed out immediately below the influent point to the system. Dispersing the inflow through a manifold rather than at a single, point-source location seems to help this. The configuration of the piping system underlying the limestone rock can also impact short-circuiting through the system. Long narrow systems that have continuous pipes running along the longitudinal axis of the system seem to short circuit through the piping system. This apparently results from the water entering the piping near the influent end of the system and traveling through the piping rather than through the limestone. Segmenting can alleviate this, or zoning the piping system by designing incremental breaks in the pipes to force the flow of water into the limestone (Danehy et al., 2002). Consideration of a system with a lower length to width ratio during the design phase also may be important in reducing short-circuiting.

The most frequently used source of organic material in vertical flow wetlands is spent mushroom compost. The function of the compost is to reduce ferric iron to ferrous iron and provide a medium for biological activity. When new systems are first put into service the mushroom compost can create very high biological oxygen demands (BOD) on the stream receiving the treated water. If aquatic life is present in the stream at the time the system goes on line, the BOD may kill much of the aquatic life present in the stream. To manage this potential problem, it is best to install a valve on the inflow pipe to the system and limit the amount of water entering the system. This allows for a slow flushing of the BOD out of the system and prevents an aquatic kill on the receiving stream.

OVEN RUN CASE STUDY

Stony Creek is a historically AMD impacted watershed located primarily in Somerset County, PA. The first major source of AMD to Stony Creek was a tributary known as Oven Run. The Oven Run AMD Abatement Project was developed under an NRCS PL-566 plan, the first in the country approved to address AMD. Six project areas were identified for abatement in the plan. Five of the six project sites required passive treatment using vertical flow systems. With completion of the first five projects by the fall of 1999, the Stony Creek turned from net acidic to net alkaline for a distance of 22 miles. The project has been very successful and has restored a recreational fishery in a stream long considered to be dead. The amazing success of this project has occurred even though three of these systems have had O & M related problems, which will be discussed below. Although the Somerset County Commissioners signed an agreement to be the responsible O & M entity under the PL-566 Plan, both BAMR and the NRCS have taken the lead role in addressing the technical problems that have arisen.

Oven Run Site A, the sixth and final site to be constructed, was just completed in the spring of 2002 using NRCS and Growing Greener funds. It consists of a passive treatment system that incorporates many design features developed as a result of lessons learned from the sites constructed earlier. Specifically, aerobic wetlands and limestone filter dams were used to remover as much ferric iron as possible prior to the vertical flow wetland. Also, an aggressive flushing system was constructed. Initial indications are that this site is functioning as designed.

Routing water sampling of the system is planned starting in the fall of 2002, after the system has stabilized.

Oven Run Site B was completed in 1999 by BAMR, using OSM ACSI and Ten Percent Set Aside funds. BAMR has continued to provide all monitoring, operation and maintenance at this site, although turning routine operation and maintenance to the Somerset Conservation District is a future possibility. Site B has a design flow of 350 gpm, although the system has successfully treated flows as high as 450 gpm. The influent has acidity between 500 and 600 mg/l, total iron between 55 and 85 mg/l and aluminum between 35 and 45 mg/l. The system consists of a deep mine drainage collection trench, a vertical flow wetland, settling pond, second vertical flow wetland and second settling pond. Until spring of 2000, the system effluent was net alkaline, with very low metals concentrations. After flows increased in the spring of 2000, effluent quality degraded to the point that net acid water was being discharged with a pH in the low 4's and elevated iron and aluminum. This situation continued, even after flows subsided. Site inspectors had observed an opening in the compost directly below the point of influent discharge into the first vertical flow system. BAMR's construction crew was brought in to construct an inflow manifold system to spread influent over a larger area and prevent the development of preferential flow paths through the compost. The expected water quality improvements did not occur, although this vertical flow system is generating about 200 – 250 mg/l of alkalinity, which is about all that can be expected. Now, concerns are being directed to the second vertical flow pond, which has steadily lost the ability to generate the additional alkalinity needed to fully neutralize the raw water. Both vertical flow systems are scheduled to be drawn down in the summer of 2002 to evaluate the development of preferential flow paths and take remedial action. One possibility is that the very aggressive flush system has actually pulled compost down into the limestone, causing the compost layer to be too thin above the pipes and allowing the development of preferential flow paths. The aggressiveness of the flush system is due to the large head differential between the system and the flush discharge point and the separation of the flushing system into 3 cells, allowing greater velocities when each is flushed individually. There is no evidence of metals plugging in either vertical flow wetland and the system continues to remove over 90% of the iron, 70 to 80% of acidity and about 60% of the aluminum (see Figure 1).

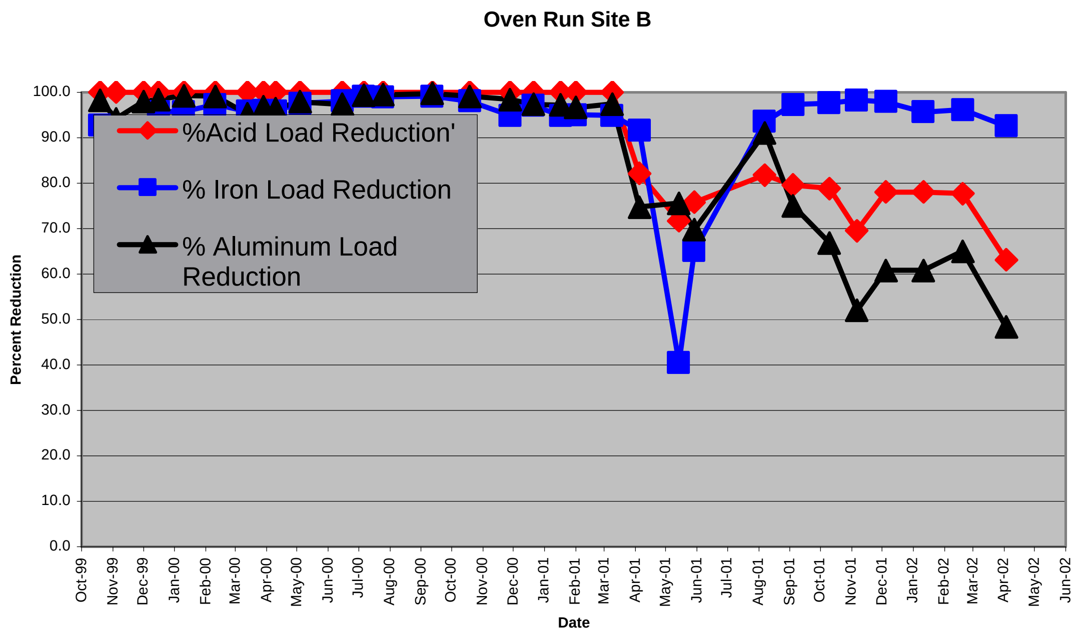

Figure 1

Oven Run Site C was completed in 1997 and consisted of backfilling a 5,000 foot long highwall using OSM Title IV funds. A small, but highly acidic, discharge from the open pit was largely eliminated. A minor seep that remains is directed to the Oven Run Site B system. Since backfilling this highwall, which was hydrologically connected to the deep mine discharge at Site B, maximum flows at Site B have been no more than half the flow measured prior to completion of this project. This flow reduction is a very important secondary benefit to completion of the backfilling project.

Oven Run Site D was completed in September of 1995 by NRCS, using PL-566 and section 319 funds. Site D treats approximately 100 gpm of moderately acidic deep mine drainage. Since beginning operation as the first completed system on Oven Run, the system worked well. In sequential order the system is composed of an initial settling pond, aerobic wetland, vertical flow wetland, settling pond, aerobic wetland, vertical flow wetland and a final settling pond. A rise in the water level in the first vertical flow wetland was noticed after the second winter of operation.

A limited flushing system in this system allowed for some flushing of accumulated metals from the system. Initially, the limited flush lowered the water level back to original levels. In subsequent years, the water level raised every winter when flow rates increased. Each time the system was flushed, the effectiveness of the flush decreased. A layer of iron was accumulating on top of the compost in the vertical flow ponds that limited the flow through the system. The system continued to treat the water flowing through it, but the quantity of water flowing through the system was controlled by the permeability of the iron on top of the compost. In the winter of 1999, some of the water began to flow through the emergency spillway and was not treated in the vertical flow wetland. This condition continued through the spring of 2002. At this point in time, approximately 50 GPM would pass through the system; any flow above this amount would bypass the system through the emergency spillways.

To remedy this situation, the Somerset County Conservation District applied for and received a DEP Growing Greener grant in the spring of 2002. To limit the iron accumulation on the compost, 3 rock filter dams were placed in the wetlands preceding the vertical flow ponds. The rock filter dams will eliminate short-circuiting of flow through the wetland and will increase the detention time in the wetland. An aggressive bottom flushing system was also installed to eliminate inert materials left behind by limestone dissolution and to remove metal accumulation in the rock layer. As part of the bottom flushing system, piping was extended to the surface of the compost and capped with threaded pipe caps. These vertical pipes will act as ports to flush accumulated iron from the surface of the compost. The caps will remain on the vertical pipes during normal operations of the system and be removed prior to flushing for surface iron removal.

Oven Run Site E was completed in 1997 with NRCS funds, and treats two moderately acidic deep mine discharges with a configuration very similar to Site B (two vertical flow wetlands and two settling ponds). Plugging of the vertical flow wetlands started to occur relatively soon after commencement of operation, which was very puzzling to the system designers. The problem was eventually determined to be the result of the limestone used in the vertical flow wetlands. While technical specifications called for a required calcium carbonate percentage, they did not specify rock meeting soundness standards as specified by the PA Department of Transportation (PA DOT, 2000). Initially, the rock produced good water quality, but the rock quickly began to deteriorate. After 4 years, hydraulic conductivity through the system was lost to the point that the system is not providing treatment. Designs have been prepared to replace the degraded rock and install an aggressive flushing system. Late summer of 2002 construction is planned for the upgrading of this system.

Oven Run Site F was completed in September of 2000 with NRCS funds. The design of this system was completed with much more knowledge about the operation and maintenance concerns of vertical flow wetlands. Experience at site D taught us that routine flushing from the bottom of the vertical flow wetland was necessary to keep the systems functioning over time. This system treats 300 GPM of acid mine drainage and consists of a vertical flow wetland, settling pond, vertical flow wetland and a final settling pond. A very intensive flushing system was designed for the vertical flow wetlands at this site. The vertical flow wetlands have a grid of 6 inch, perforated pipes on 11 foot centers, under the limestone. These pipes outlet to two, 12 inch pipes that are at opposite ends of the vertical flow wetland. The flow out of the system when these two pipes flow is approximately 5000 GPM per pipe, at the beginning of the flush. Experimenting with the sequencing of opening valves and the duration of flushes has provided some empirical observations of the flushing events at this site.

Observations were made while opening only one valve at a time, with alternate opening and closing, after 30 minutes of flow, and opening both valves at the same time until the vertical flow wetland was drained. With both flushing scenarios, the flush water was initially very turbid. With the alternate opening and closing of valves, the effluent water began to clear and become less turbid after 30 minutes of flushing. The amount of turbidity decreased with each successive alternate opening and closing of valves. When both valves were opened simultaneously and the water was allowed to flow until the system was drained, the effluent water remained very turbid during the entire time of the flush, approximately 3 hours. Since this system was constructed with an aggressive flushing system in 2000, quarterly flushing has been completed. There has been no indication of rising water levels in this system as were noted at Site D, where only a limited flushing system was designed. These empirical observations need to be followed by more controlled flushing experiments that involve water quality testing during the flush to calculate quantities of metals flushed from the system.

CONCLUSIONS

The future of passive treatment of AMD is dependent upon resolution of the long term O, M & R issues related to these systems. Implementation of the DEP Workgroup recommendations is underway and starts to resolve these issues, particularly from an administrative standpoint. However, resolution of many of the technical concerns may be more difficult. One of PA's leading AMD treatment consultants, Hedin Environmental, received a Growing Greener grant to evaluate design and operation of flushing facilities. This work was initiated with a workshop attended by a number of government and consulting personnel to gather and organize existing data on vertical flow systems in order to design the most efficient systems (Workshop Proceedings, 2002). The technical issues fall under several general categories that are discussed below.

Use of Mushroom Compost:

The use of mushroom compost in vertical flow wetlands to promote biological activity and facilitate the conversion of ferric iron to ferrous iron is a widely accepted practice (although, more recent thinking is that this conversion is not a complete one; ferric iron is observed being flushed from these systems). Mushroom compost is also used in anaerobic wetlands to encourage sulfate reduction reactions and in aerobic wetlands to promote plant growth. When AMD systems are constructed using mushroom compost, sample analyses have shown a significant biological oxygen demand (BOD) present during the first week to 3 months the system is in operation. This BOD can present devastating impacts on receiving streams if any aquatic life is present. Frequently, the acid water being treated has already devastated aquatic life to the level that there is little need for concern. However, in situations where aquatic life is present or where there are downstream municipal water supplies, the management of the outflow of BOD from the system is imperative. The simplest method to control the initial flow of BOD is to strategically place piping and valves in the system so that the majority of the AMD can be bypassed around the system while a small flow is allowed to move through the system. The small flow will, with time, reduce the BOD to levels that are not harmful to aquatic life. Once this condition is reached, the flow of AMD through the system can gradually be increased until all of the AMD is flowing through the system. Recent trends have been toward a reduction in compost from early designs, where compost thickness was as high as two feet. Experience on the NRCS Oven Run sites indicates that 6 inches of compost is adequate to promote biological activity and facilitate conversion of ferric iron to ferrous iron. Larger quantities of compost take longer to dissipate the BOD and long-term odor problems can be a concern in residential areas. Another consideration, however, is that too little compost may contribute to short-circuiting, as well as possible rapid depletion of fine limestone within the compost and a possible loss of biological activity once the pH drops. BAMR has recently dropped compost specifications from 2 feet to 1 foot to reduce BOD generation while still providing adequate compost to address the other concerns.

Short Circuiting:

In Oven Run, we have learned that the flow through systems with under draining flush capabilities may short circuit in a number of ways. Preferential flow patterns may develop as a result of shifting compost below inflow points and possibly even above flush pipes on systems with aggressive flushing. Other short circuiting may occur directly through the flushing pipes. In long, narrow systems, with flush piping extending the full length of the system, there is a high potential for water to enter the flush pipes at the inflow end of the system and travel through the pipe instead of through the rock. This short-circuiting does not allow adequate detention time in the limestone rock for treatment of AMD. Short-circuiting can be reduced using a couple different methods. Distribution manifolds that evenly distribute the water throughout the vertical flow wetland prevent water from entering at one point and entering the flush system. This also keeps compost from being shifted immediately below the inflow point. Another method of preventing short-circuiting is to incrementally cap the longitudinal flush pipes so water is forced to leave the flush pipes and flow through the limestone rock (compartmentalizing the flush systems). On larger flow discharges, the use of both of these techniques is recommended to maximize water to rock contact. Minimizing the length to width ratio also should be considered during design.

Flushing:

Experience in Oven Run and other watersheds over the last seven years has clearly shown that vertical flow wetlands treating highly mineralized AMD that are not designed and operated with an aggressive flushing system will experience plugging with time. In vertical flow wetlands that treat acid mine drainage with dissolved iron and aluminum, the accumulation of precipitated metals in the rock will fill the rock voids, eventually plugging the system, and cease to treat the mine drainage. Bottom flushing of vertical flow wetlands has proven to be an effective way of removing accumulated precipitates from these systems. Long duration, high volume flushing performed on a regular schedule has maintained hydraulic conductivity through the Oven Run Site F system. The system has continued to produce high quality water since construction. Figure 2 illustrates how the water quality improves as it moves through the system.

Some system designers have recommended limiting the number of holes in the perforated pipe to increase the velocity of flow through each perforation in the pipe. The number of perforations in the pipe is the limiting factor determining the quantity of water leaving the system. There are some concerns with this type of design. One concern is that the distance between holes in the pipe becomes too great and the area of influence of the perforation is less than the distance between perforations. In this case, there potentially could be “dead areas” between perforations where little flow occurs, which would eventually cause the rock to plug with metal precipitate. Another concern is that limestone rock placed directly on the perforated pipe could greatly reduce the capacity of the perforations if a rock lodges in a perforation. If this happens, the distance between perforations becomes even greater, increasing the potential for "dead" areas. Other designs currently being evaluated include those using multi-tiered flush piping and those that do not use compost at all. Determining the best design for these systems is an ongoing process. Hedin Environmental has retained an engineer to evaluate current system designs and make recommendations for future designs. A draft paper, currently being circulated for comment, recommends increasing flush velocities to assist in the removal of retained solids by dividing the under drain systems into multiple cells and designing the header pipes for gravity flow to provide for even flow distribution (Langese, 2002).

Rock Quality:

The quality of the limestone rock used in vertical flow wetlands is somewhat dictated by the local commercially available sources of limestone. In western Pennsylvania, there are several sources of limestone that perform well over long periods of time. It is important to specify stone that is durable and will not deteriorate when exposed to acid. Specifying rock that meets the soundness standards specified by the Pennsylvania Department of Transportation (PA DOT) should ensure the integrity of the system with regard to ability to transmit water. Early in the implementation of the Oven Run Site E project, the soundness of the limestone was not specified by NRCS. Rock was provided that met the specified chemical standards, but was not from an approved PADOT quarry. This is believed to have caused the system to fail.

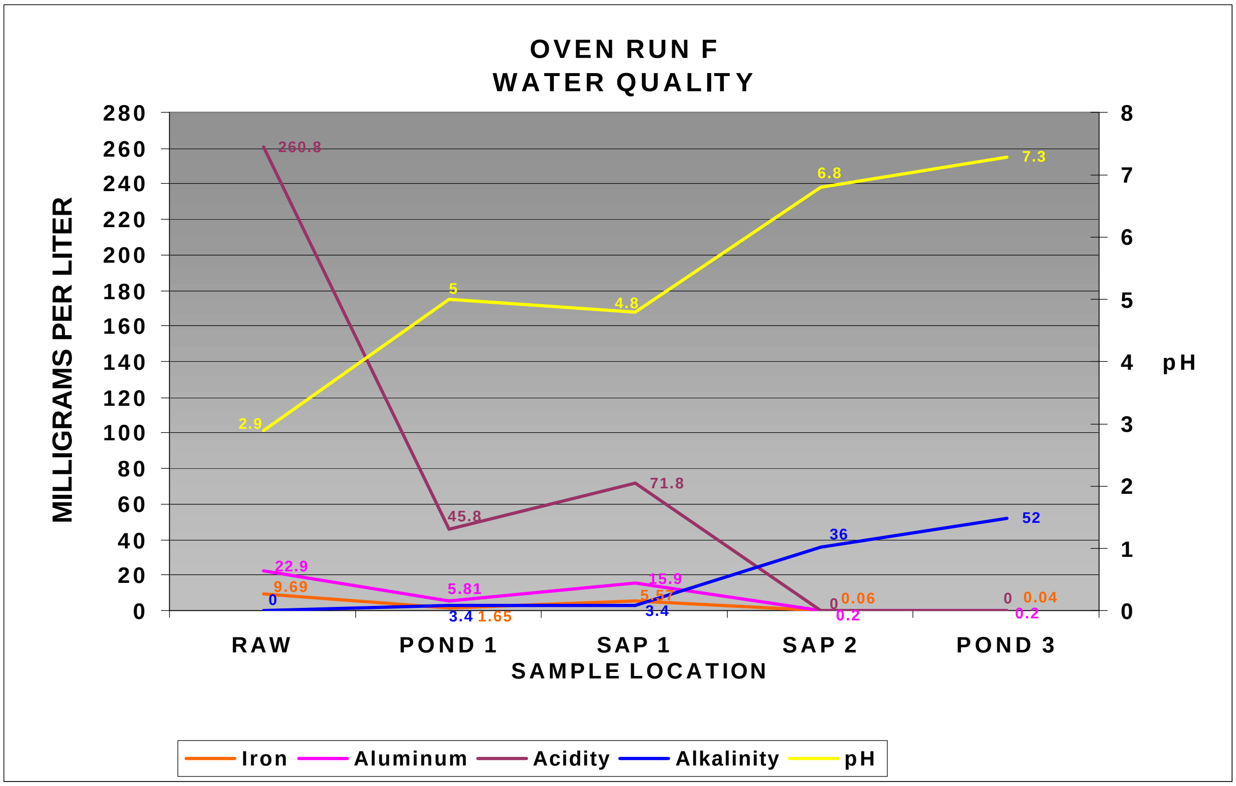

Figure 2

It is also important to specify a minimum of 80% calcium carbonate as determined by ASTM C-114. It is important to note that calcium carbonate equivalent (CCE) is not specified but elemental calcium carbonate is. Also, the maximum content of elemental magnesium should not exceed 2% and inert material (e.g. silica) should be less than 15%.

The above discussions should help to emphasize the need to have a knowledgeable, reliable entity to provide for long-term O, M & R. The failure to do so will result in the eventual failure to adequately treat AMD and the loss of millions of dollars worth of public investment. Gains in the restoration of aquatic habitat will also be lost. The design of these systems is expected to continue to evolve as more is learned about long-term operation. Passive treatment of AMD is expected to be an important aspect of watershed restoration into the foreseeable future. O, M & R improvements will ensure the continued success of this restoration work.

REFERENCES

Commonwealth of Pennsylvania, Department of Environmental Protection. Bureau of Abandoned Mine Reclamation. Project Files.

Danehy, T. et al. 2002. Vertical Flow Pond Piping System Design Considerations. Proceedings: American Society of Mining and Reclamation. Lexington, KY. June 9-13, 2002.

Lagnese, K. M., P. E. 2002. An Engineering Evaluation of Vertical Flow Pond (VFP) Flushing Systems (draft). Prepared for Hedin Environmental.

Commonwealth of Pennsylvania, Department of Transportation. 2000. Specifications. Publication 408.

U. S. D. A. Natural Resources Conservation Service. Somerset Technical Office. Project Files.

Watzlaf, G. R., Kairies, C. L., Schroeder, K. T., Danehy, T. and Beam, R. 2002. Quantitative Results from the Flushing of Four Reducing and Alkalinity-Producing Systems. Proceedings: West Virginia Surface Mine Drainage Task Force Symposium.

Workshop Proceedings: Vertical Flow Minewater Treatment Systems. Ebensburg, PA. January 9, 2002.

Attachment A

DEPARTMENT OF ENVIRONMENTAL PROTECTION

FINAL RECOMMENDATIONS OF THE LONG TERM OPERATION, MAINTENANCE AND REPLACEMENT WORKGROUP

November 15, 2001

An increasing number of watershed groups, as well as many Federal, State and local agencies, have become active in watershed restoration over the past several years. As a result, a large number of restoration projects are being funded and constructed. Water quality and aquatic habitat improvements are occurring as these projects are implemented. The need for long-term operation, maintenance and replacement (O, M & R) has been increasingly recognized as a requirement to ensure the success of watershed restoration projects. In Pennsylvania, a total of nearly $93 million of public money has been spent on these projects since 1988 (see attachment A). The establishment of the Growing Greener grant program has greatly accelerated this effort. The failure to maintain the systems being constructed under these projects could have detrimental impacts to watersheds that are beginning to support an increasing number of stream uses. As a result of growing concern over this issue, the Department's Greener Team established a workgroup to provide recommendations to address this need. This workgroup consists of individuals from Federal, State and local governments, as well as private consultants and watershed group officials. All have had extensive experience in the operation and maintenance of watershed restoration projects.

It is important to note that, for the purpose of defining needs and determining costs, the workgroup defined long-term O, M & R as system operation and maintenance, plus one system replacement at the end of the design life of the project. Also of note is a decision by the group to include all publicly funded watershed restoration projects constructed through 2001, when determining costs associated with existing systems.

O, M & R Plan

An O, M & R Plan, developed by the project sponsor, is an integral part of providing for operation and maintenance of watershed restoration projects. The basic elements of an O, M & R plan include: a written agreement with the entities responsible for O, M & R, identification of tasks to be completed, development of a schedule and determination of responsible parties and costs. Plans must become a "deliverable" of all new implementation grants. For existing projects that have no O M & R plan, site-specific plans will need to be developed prior to receiving funds to address O, M & R.

Operation, maintenance and replacement concerns should begin at the initial site inventory of a project and continue through all phases of project development. Water quality information, along with flow measurements, should be looked at critically with respect to future operation and maintenance. If a site requires intense operation and maintenance to function, the sponsors of the project need to understand the intensity and potential cost. Once the decision is made to move ahead with project design, the focus should be to make the operation and maintenance of the system as easy as possible. Prior to project implementation, the sponsors need to understand what it is they need to do and at what frequency. Additional training may need to be provided to facilitate a more detailed understanding of operation and maintenance.

In developing an O, M & R plan, the following should be considered:

Operations - Sponsors need to demonstrate an understanding of, and the ability to perform, routine duties, such as:

Inspections (including water sampling and flow measurements);
Litter control;
Vegetation control;
Mechanical maintenance (including flushing);
Insect and vector control;
Physical stability and erosion control.

Maintenance - Sponsors need to demonstrate an understanding of, and the ability to perform, more intensive items that may take considerable dollars and time to accomplish, such as:

Removal and disposal of accumulated precipitate or sediment;
Maintenance of channels;
Industrial cleaning of pipes;
Repairing damage after major storm events;
Repairing cracks or leaks;
Adding limestone, compost, sand or gravel;
Repairing vandalism damage;
Adjusting grade or outlet structures.

Replacement - Systems have a designed life expectancy; once that design life is exceeded, much of the system will need to be recharged or replaced. Replacement will involve much of the same effort originally needed to construct the system. Changes in technology and water quality and quantity will need to be considered to determine if the size and/or design of the system must be changed. Replacement considerations include:

Estimating BMP (Best Management Practice) design life;
Determining replacement responsibility, including a successor, in the event of the original project sponsor's inability to carry out these responsibilities;
Determining approximate costs for the following possible needs: removing accumulated sediments, replacing defective valves, water control structures, re-sizing the system to accommodate changed water quality or quantity, recharging organic matter layer on wetlands, recharging limestone rock.

An O, M & R Plan should include:

- Narrative describing O, M & R needs and identifying responsible parties
- Signed maintenance agreement with all parties, including property owners
- O, M & R Site Map that includes BMP's, flushing points, monitoring points (water sample locations, benchmark cross sections, etc.)
- Site specific instructions
- "As-built" plans

Long-term Cost Analysis

Long-term costs are analyzed in many business and government applications. The starting point for most analyses is a spreadsheet that projects costs over the lifetime of the BMP. Costs are often divided into tasks such as site inspections, sample collection, sample analysis, sludge management, flushing, and reconstruction. A long-term cost spreadsheet should be developed for all projects early in the planning process. The construction of this spreadsheet will help sponsors to recognize long-term responsibilities and also encourage them to identify mechanisms that will legitimately lessen the long-term costs of their projects.

The workgroup collected information on long-term costs of BMPs by reviewing existing policies, interviewing technology experts, and by analyzing current cost data. The workgroup did not find established O, M & R cost estimates for mine drainage treatment systems, so estimates were developed from Department, Natural Resources Conservation Service (NRCS), non-profit and consultant experiences. These data were used to develop spreadsheets that projected long-term O, M & R costs for specific mine drainage BMPs. Development of the spreadsheets required assumptions about the time period over which to project costs and whether to include a BMP replacement in the extrapolation. The workgroup decided to analyze 25 years of costs and to include one replacement in the calculation.

The spreadsheets were analyzed in two ways. The first method was to calculate the present value of the long-term costs. The method requires financial assumptions about rates of inflation and investment return. The result of this calculation is a sum of money that, if the financial assumptions are realized, will yield proceeds adequate to cover all anticipated long-term costs. Our analyses assumed a 3% inflation rate and a 6% rate of return, or a net rate of return of 3%. While this may seem conservative, it is consistent with long-term economic trends in the U.S. It is also consistent with similar analyses of long-term AMD treatment costs being conducted by the Department for permitted mines. The present value analysis yields a sum of money that can be placed into perspective by comparing it to the BMP’s original construction cost. On average, the present value of the long-term O, M, & R costs were approximately 60% of the construction costs. Thus, if the Department wanted to fully fund a $100,000 passive treatment project, it should plan on placing $60,000 in an interest-bearing account at the time of construction. If the cost projections and financial assumptions are correct, no more funds should be required for 25 years.

A second analytical method calculated the annual costs of an on-going O, M & R program. Instead of paying all the anticipated long-term costs in the first year, only those expenses anticipated for the current year would be paid. Each year, for 25 years (the workgroup’s analytical timeframe), the annual O, M & R costs would be paid. We calculated the average annual cost by summing all anticipated O, M & R costs and dividing by the analytical period (25 years). This average O, M & R cost was related to the construction cost to calculate the O, M & R factor. On average, most AMD passive treatment technologies had an average annual O, M & R factor of 4%. Thus, a $100,000 project would require an average of $4000 per year in annual costs. The actual costs would vary widely because major maintenance costs and replacement costs – both high expense items – occur infrequently and generally toward the end of the BMP lifetime. The factor does not account for inflation. Since most watershed restoration projects have been constructed relatively recently, not accounting for inflation shouldn't be a problem at this time. If the Department decides to fund O, M & R using the O, M & R factor, it should regularly adjust the base value of construction to account for inflation in the future.

The estimated O, M & R factors varied with the type of watershed restoration project. Table 1 shows the range in factors. Most of the BMPs being implemented with Growing Greener funds are in the 3-5% range. While the AMD factors were based on actual experiences of several workgroup members, the non-AMD estimates were derived from informal surveys of the following sources: NRCS, the Center for Watershed Protection, the Keystone Stream Team, PA DEP, MD DOE, Universities and consultants. These sources were able to provide good input concerning O & M (particularly the NRCS, which just completed an evaluation of agricultural BMP's by June C. Grabemeyer, Agriculture Economist, East Lansing, MI), but were less certain about replacement costs. The group decided that 4% was a good average O, M & R factor to use in estimating long-term costs for all types of restoration projects, for the purpose of estimating funding needs.

Table 1: Average O, M & R Factor for Watershed Restoration BMP's

Agricultural BMPs	**4%**
Stream Restoration BMPs	4%
Stormwater Management BMPs	3%
AMD Vertical Flow Systems	5%
AMD Anoxic Limestone Drain Systems	4%
AMD Compost Anaerobic wetlands	4%
AMD Pyrolusite© Systems	3%
AMD Open Limestone Channels	1%

The workgroup broke down the long-term O, M & R factor into cost categories. For a passive treatment system that has a 5% annual factor, system reconstruction accounted for 40% of the costs, routine operations (inspections, sampling, flushing) accounted for 20%, water sample analyses accounted for 10%, and general and unscheduled maintenance and repairs accounted for 30%. This breakdown was valuable because it showed that well-organized project sponsors should be able to cover up to 60 % of the estimated O, M & R costs by assuming all or part of the non-replacement responsibilities.

The workgroup decided to use the O, M & R factor method to analyze costs and make recommendations concerning the amount of funds needed to address O, M & R on a long-term basis. This determination was made based on feedback received from Executive Staff and others that up-front, lump sum funding of O, M & R was not likely to be pursued by the Department.

A difficult issue within the analysis of long-term costs was the cost of lab analyses of water monitoring samples collected. The water sampling cost analysis was based on the Department’s cost of $65 per sample (approximate cost of the Bureau of Abandoned Mine Reclamation's 711 Standard Analysis Code, used for routine AMD samples). Private laboratories experienced with AMD analysis can provide reliable analyses for $15-35 per sample, although inexperienced private labs sometimes provide inconsistent results. Two possible options were discussed with regard to sample analyses. One is for the Department to consider certifying private laboratories for AMD analysis and encourage watershed groups to use private labs, thereby decreasing long-term costs. Another option is for the Department to develop a regular funding source for analyses of watershed samples currently being collected under Mineral Resource Management's collector numbers. Costs can be reduced by determining a Standard Analysis Code that provides the minimum number of parameters needed to evaluate system performance.   The advantages of this option are that lab results would be made available more easily to the Department and the quality assurance issues are addressed. However, it may be possible to address the quality assurance issue with private labs through a certification process. The workgroup has decided to recommend both options so that watershed groups can utilize what works best on an individual basis. The workgroup believes that the Bureau of Mining and Reclamation's existing SOAP/ROAP certification process is the best vehicle to use to certify private labs.

Implementation (Funding Engine)

Various funding options were reviewed by the workgroup to provide for the sustainability of existing and future facilities that benefit the general public and improve the water resources of the Commonwealth.

True sustainability needs local community ownership and involvement. Public-private partnering develops healthy interdependence (working relationship) between state agencies and the watershed residents, including volunteers, students, service groups, private industry, environmental professionals, and other interested parties.

Some project sponsors have developed and are implementing long-term plans; however, many groups currently do not have the means or ability to do this.

The workgroup developed recommendations for a support strategy to enable groups to provide for long term O, M & R. It includes the following:

- Commonwealth: develop a source of funding and create a grant funding category for the O, M & R of existing and future construction projects;
- Sponsor: provide available resources for total or partial O, M & R;
- Other: provide additional O, M & R support by use of the Bureau of Abandoned Mine Reclamation (BAMR) construction/maintenance crews, the 12th Congressional District Equipment Center, and local/private industry.

Funding Options:

The workgroup calculated the approximate initial annual funding needed to address long-term O, M & R at $1.86 million, using the following method. This amount, discussed in both options below, has been calculated by determining the cost of providing for 50% of the average 4% O, M & R factor of $93 million for existing projects. This amount is expected to cover major maintenance (10%, or approximately 1/3 of the expected total maintenance costs) and replacement (40%) needs. It is expected that watershed groups and their local partners, Department assistance with lab costs and BAMR and 12th Congressional District Equipment Center assistance with maintenance will make up the remaining 50% of the O, M & R factor.

The following are two alternatives developed by the workgroup as possible solutions to the funding challenges associated with long-term O, M & R. One of these alternatives, or a combination thereof, may ultimately be seen as the appropriate funding solution.

<u>Option 1: Funding O, M & R on an annual-basis ("pay as you go")</u>

- Up to 10% of Growing Greener funds are earmarked for funding of O, M & R projects; the amount not spent for O, M & R is released to provide additional new project funding.
- The Secretary's approval is needed if demand is such that more than 10% of Growing Greener funds are necessary.
- Some of the 10% is held back for emergency O, M & R projects, with this money released for new project funding at the end of the fiscal year.
- The delivery system would be the existing Growing Greener Grant Center, using an additional funding category on the grant application form.

Advantages:

With this option, if the O, M & R amount is not fully requested, then the balance would be available for funding new projects. At the current Growing Greener funding level of $50 million per year, it is expected that less than 10% of this amount will cover all major maintenance and replacement needs for the foreseeable future (expected to be about $1.86 million for existing projects).

Disadvantages:

This option requires the continuation of Growing Greener beyond year five. At this time, continuation is considered likely, but is not a certainty. Also, if Growing Greener is continued, the funding level may be reduced, thereby reducing the amount available for O, M & R. Another disadvantage is that it will take away from money to be spent on new projects, unless the Legislature authorizes increased Growing Greener funding to make up the difference.

<u>Option 2: Funding O, M & R for the long-term ("set aside")</u>

- The PA legislature provides an annual budget appropriation for long-term needs (or, an existing funding source is found within the Department) at an initial rate of $1.86 million per year.
- The amount appropriated will need to increase annually based upon the amount spent on

construction projects annually. For example, if $25 million worth of projects is constructed in 2002, there will be $93 million plus $25 million, or $118 million worth of constructed projects; therefore, $2.36 million will need to be appropriated for O, M & R the following year (50% of 4% factor multiplied by $118 million).

- The annual appropriation would be placed in a "set-aside" fund administered and managed by the Commonwealth. Applicants would apply for funds using the established Growing Greener framework. Any money left over at the end of the year would stay in the fund. The fund would be allowed to build up so that, when needs become greater (as systems need replaced or major floods or other catastrophes occur), the funds would be available to cover that need.

Advantages:

This option would leave the current project funding amounts for Growing Greener intact and would not be dependent upon the continuation of Growing Greener beyond year five. It would allow an accumulation of funds to deal with long-term needs that are expected to increase as systems age and need to be replaced.

Disadvantages:

This option would require legislative action to appropriate funds. It would require the establishment and administration of an interest-bearing fund. It would require tracking of implementation projects from all public funding sources in order to know how much new construction takes place on an annual basis, to determine funding amounts.

Actions Needed by the Department for Implementation

- Select a funding option and appropriate funds for O, M & R support of existing and future projects.
- Develop a fund/program management system, including a Growing Greener O, M & R project category and related activities (including changes to scoring and application guidance).
- Require the development of O, M & R plans prior to the provision of O, M & R funds for existing projects and as a deliverable under construction contracts for new projects.
- Provide O, M & R training for watershed groups via Growing Greener workshops and watershed conferences, with assistance from others.
- Improve DEP capacity to assist groups with O, M & R:
    - Provide improved capacity of BAMR's construction crews to assist with major maintenance.
    - Dedicate funds to support Mineral Resource Management sponsored lab analysis for watershed groups and determine an appropriate Standard Analysis Code.
    - Adopt SOAP/ROAP lab criteria and cost guidelines for watershed sample analysis.

Appendix A
Publicly Funded Restoration Projects

	NRCS	319	BAMR	WRPA	OSM	G2	Totals
1988	$125,000	$0	$0	$0	$0	$0	$125,000
1989	$150,000	$0	$0	$0	$0	$0	$150,000
1990	$0	$75,000	$0	$0	$0	$0	$75,000
1991	$75,000	$200,000	$0	$0	$0	$0	$275,000
1992	$12,000	$225,000	$0	$0	$0	$0	$237,000
1993	$0	$400,000	$0	$0	$0	$0	$400,000
1994	$0	$675,000	$0	$0	$0	$0	$675,000
1995	$152,066	$850,000	$0	$0	$0	$0	$1,002,066
1996	$0	$1,000,000	$0	$0	$0	$0	$1,000,000
1997	$183,959	$275,000	$1,502,626	$0	$0	$0	$1,961,585
1998	$34,314	$1,700,000	$1,664,737	$0	$0	$0	$3,399,051
1999	$274,454	$3,400,000	$2,470,041	$688,458	$262,240	$25,350,000	$32,445,193
2000	$109,284	$2,700,000	$643,873	$296,558	$567,800	$21,050,000	$25,367,515
2001	$200,000	$3,700,000	$1,390,401	$0	$321,400	$20,140,000	$25,751,801
							$92,864,211